national accelerator laboratory

EXP-49
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ACCELERATOR EXPERIMENT: Evaluation of the Scheme for Tune Measurement by Closed-Orbit Distortion

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Experiment Dates: 15 August 1973, 17 August 1973, 22 August 1973

A series of meausrements have been made with the prepulse to determine the precision and reliability of the tune value determined by kinking the closed orbit with a correction dipole.(1) The objectives were to test measure/remeasure consistency and systematic effects due to the strength and location of the orbit kink. Almost all the work reported here is for the vertical plane for which the machine behavior was expected to be simplest.

The typical measurement procedure is as follows. The unperturbed closed orbit is stored in a position detector file. A correction dipole bending in the plane of interest is changed by an amount sufficient to make an obvious difference in the orbit. Less than 10 units on a vertical dipole is generally fairly well in the "noise"; greater than 70 units kills the beam at 8 GeV. The perturbed orbit is stored and then the difference between the perturbed and unperturbed files is displayed. An experimental version of the closed orbit page (p. 51) contains a routine to fit the displayed data to the form

$$x_i = A \cos\left[\nu\ (\theta_i - \pi)\right] + Bx_{pi}\ (\theta_i).$$

The origin of the phase θ_i is the location of the kink. A, B, and ν are the fitted coefficients and x_{pi} is the x_p value for horizontal measurements and a constant 1 for vertical measurements. The fitting program uses only the 96 regular cell detectors for which β = const. A single measurement of this sort takes less than a minute; an appreciable part of the time is the wait for the fit.

Figure 1 shows a set of ν_y measurements taken vs quadrupole current (increasing toward the left). The measurements were taken using a single kink location. In this case the difference was taken between orbits perturbed by $\pm$ 40 units The resulting difference orbit amplitude varied between about .58" at ν = 20.25 and .45" at ν = 20.43. The error bars of $\sim$ .005 are determined by the fitting program. It is clear that the quantity "ν" being determined is linearly dependent on quad current to $\sim$ .001 over a reasonable current range. That this "ν" is rather close to the tune of the machine is indicated by the fact that our attempt to measure ν at a B-Q of 12.4* was frustrated by killing the beam. This point would be a tune ν = 20.495 according to Figure 1.

Ideally neither the kink location nor amplitude should affect the measured valve of ν. The variation of measured ν_y vs amplitude of a kink at VE29 is shown in Figure 2. The error bars are a strong function of orbit distortion amplitude. Data for amplitude less than .2" are of limited significance presumably due to random sensor error. This random error is believed to be $\lesssim$ .1" rms. No systematic trend is manifest in the plot. The data points are not all independent because they were derived by differencing a set of seven independent closed orbits consisting of the unperturbed orbit and orbits perturbed by bump amplitudes of $\pm$ 60, $\pm$ 40, and $\pm$ 20 units. During the twenty minutes or so occupied by the data-taking machine conditions may have changed; the unperturbed orbit, however, was watched and showed no significant changes. Measure/remeasure stability with same parameters at times an hour apart was better than .01 in ν_y.

The variation of measured ν_y with respect to kink location is plotted in Figure 3. Data of two different amplitudes have been used because Figure 2 suggests no systematic amplitude dependence. The data would have been of greater interest if

*The units of B-Q apparently are Gauss, i.e. the field the difference current would produce in the dipoles.

the large amplitude had been used throughout because the error flags for the low amplitude data cover a rather wide range. However, within the range of $\sim \pm .01$ one sees no clear variation of measured ν with position.

The observations in Figure 2 and 3 were made on 22 August. Observations on amplitude dependence made on 15 August with the machine running at 300 GeV were less extensive but qualitatively different. Data taken at this time had the appearance of significant variation with both amplitude ($\Delta\nu \sim .02$) and position ($\Delta\nu \sim .05$) of the kink. Figure 4 showing the amplitude variation looks smoothly systematic. The average octupole moment computed from the measurements plotted in Figure 4 by the formula[2,3]

$$\Delta\nu_y = \frac{\beta_y \, B''' \, l_y^2}{32\pi \, B\rho}$$

is

$$\overline{B'''L} \simeq 1.5 \times 10^4 \text{ kG/m}^2.$$

This value is in reasonable agreement with the amount of octupole used to (approximately) compensate the dependence of ν on ping amplitude.[4] However, the two curves taken from different kink locations do not appear headed toward the same unperturbed ν value so the whole argument is very questionable. Before expending much effort in trying to analyze these perhaps erratic observations in terms of machine parameters it is planned to carry out some measurements at high field where fewer unknown short-term accelerator parameter changes are expected.

The implications of the data reported here are that:

(1) A simple tune measurement accurate to $\sim .02$ can be taken in a few seconds with little worry about non-linear effects.

(2) The largest practical perturbation amplitude should be used to reduce the contribution of random sensor error.

(3) Numerical fitting precision $\sim .001$ can be obtained so that with adequate control of experimental conditions tune differences of this order may have use in investigating non-linear effects.

(4) It is desirable to find a domain in which the accelerator behavior is sufficiently simple and controlable to validate measurements of higher apparent precision.

Notes

1. J. MacLachlan and J. Sauer, TM-436
2. CERN Lab II Report, Lab II-Dl-PA/EJNW/pd
3. S. Ohnuma, private communication
4. R. Stiening, private communication

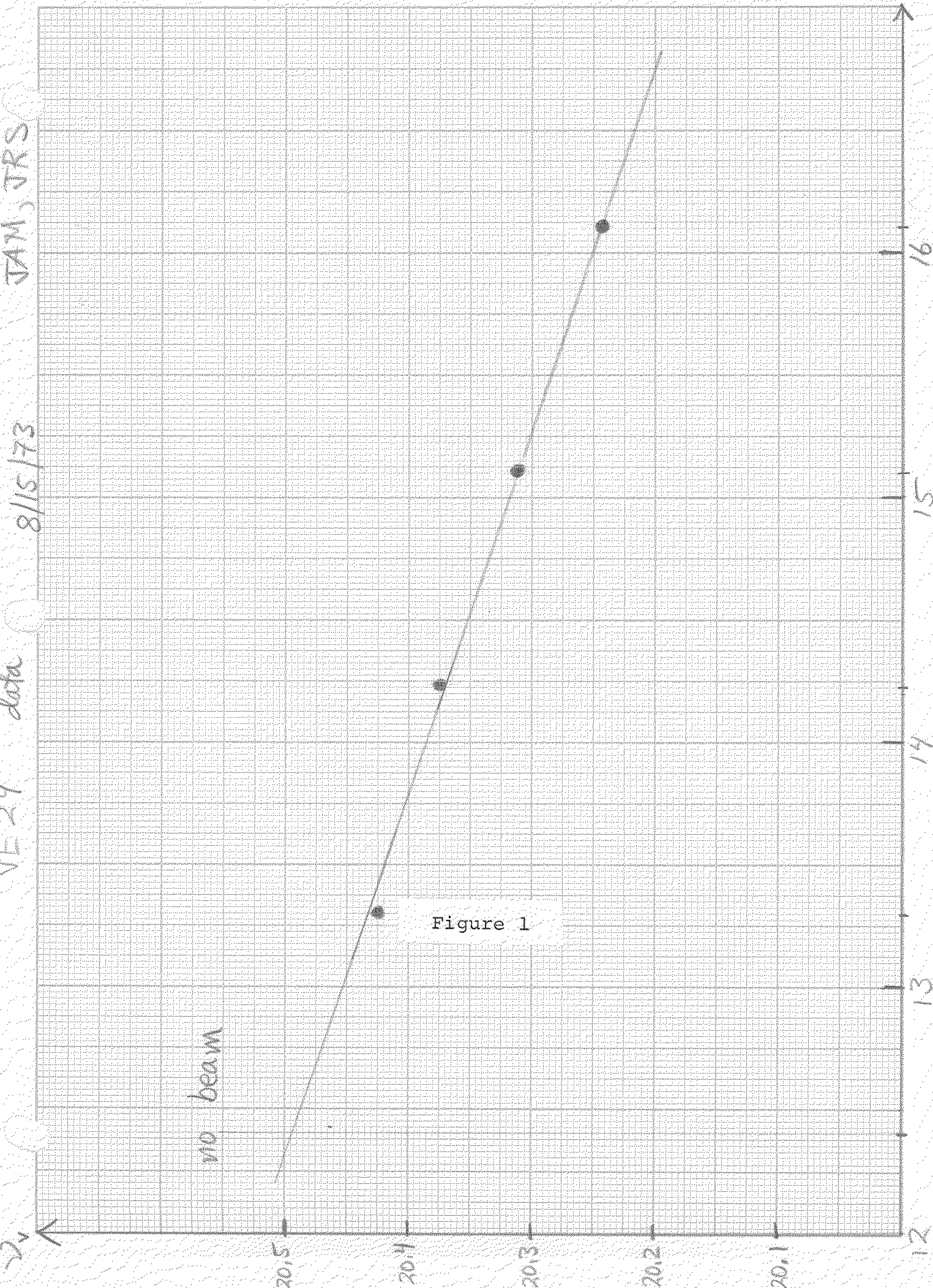
VE 29 data 8/15/73 JAM, JRS
B-Q
no beam
12
13
14
15
16
20.5
20.4
20.3
20.2
20.1

Figure 1

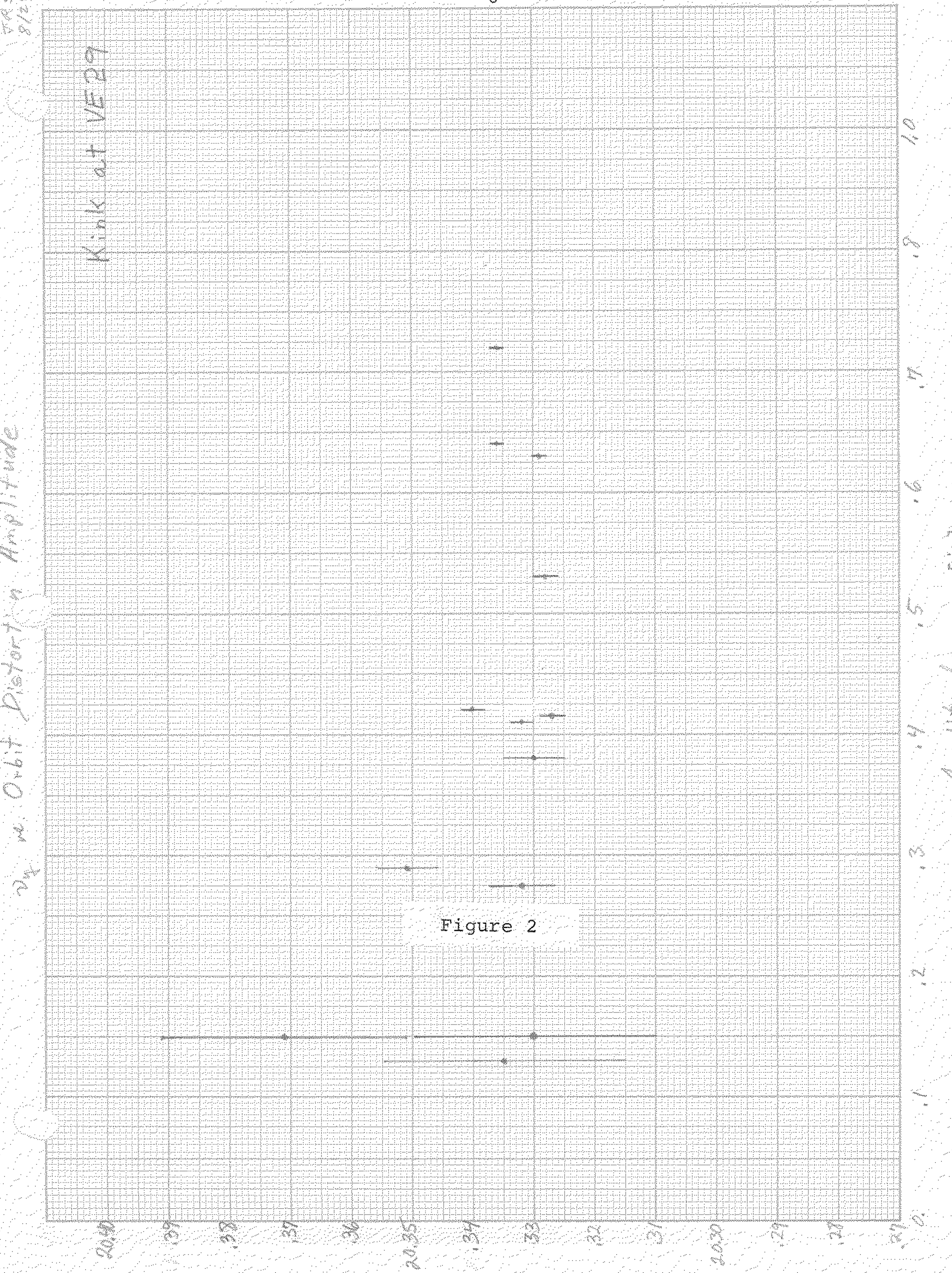
Kink at VE 89
νy vs. Orbit Distortion Amplitude
Amplitude [in]
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
20.40
.39
.38
.37
.36
20.35
.34
.33
.32
.31
20.30
K+E 20 X 20 TO THE INCH 46 1240
KEUFFEL & ESSER CO.

Figure 2

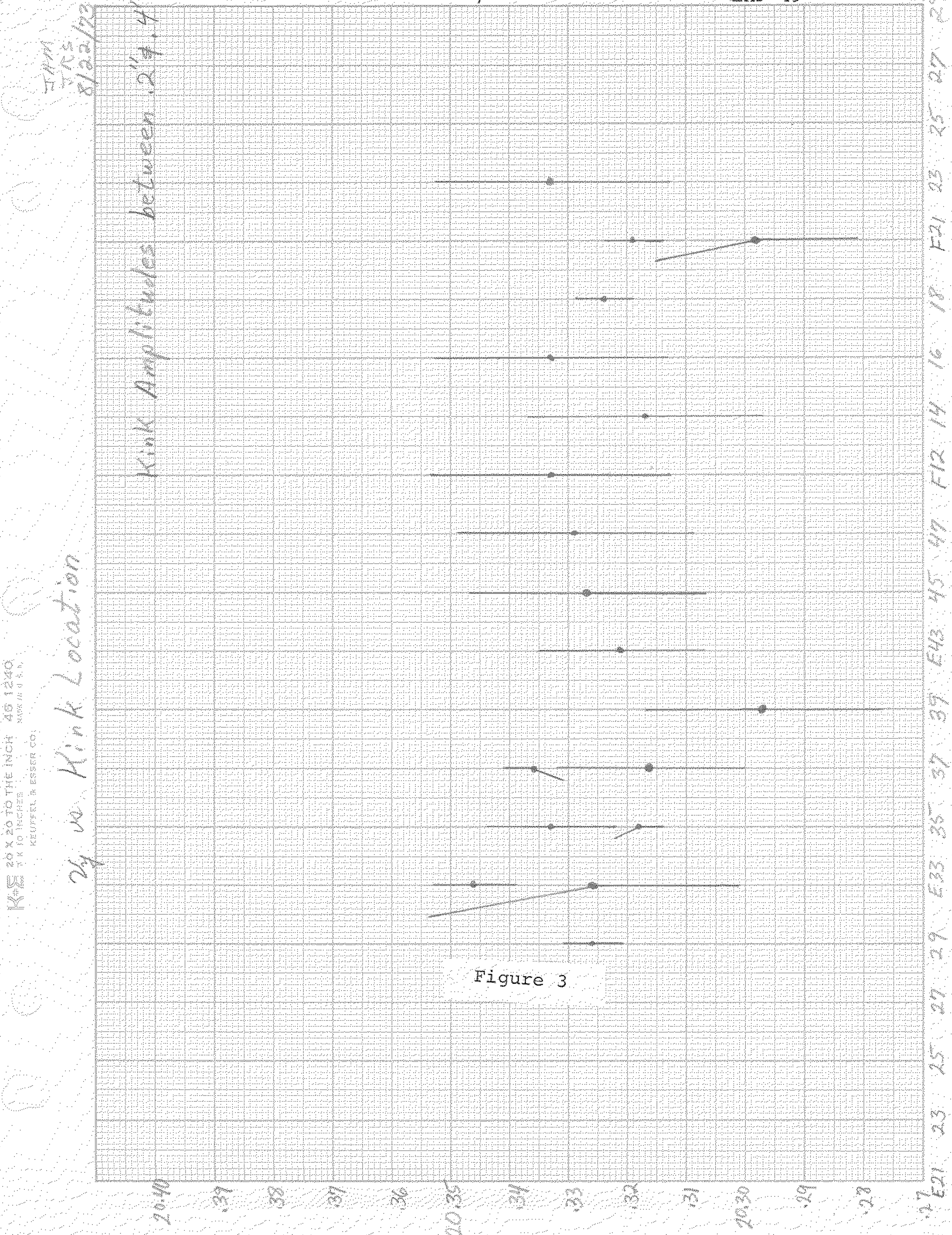
νy vs Kink Location
Kink Amplitudes between .2" & .4"
20.40
.39
.38
.37
.36
20.35
.34
.33
.32
.31
20.30
.29
.28
.27
E21 23 25 27 29 E33 35 37 39 E43 45 47 F12 14 16 18 F21 23 25 27 29

Figure 3

V_y vs. Amplitude 8/15/73 JMM JRS

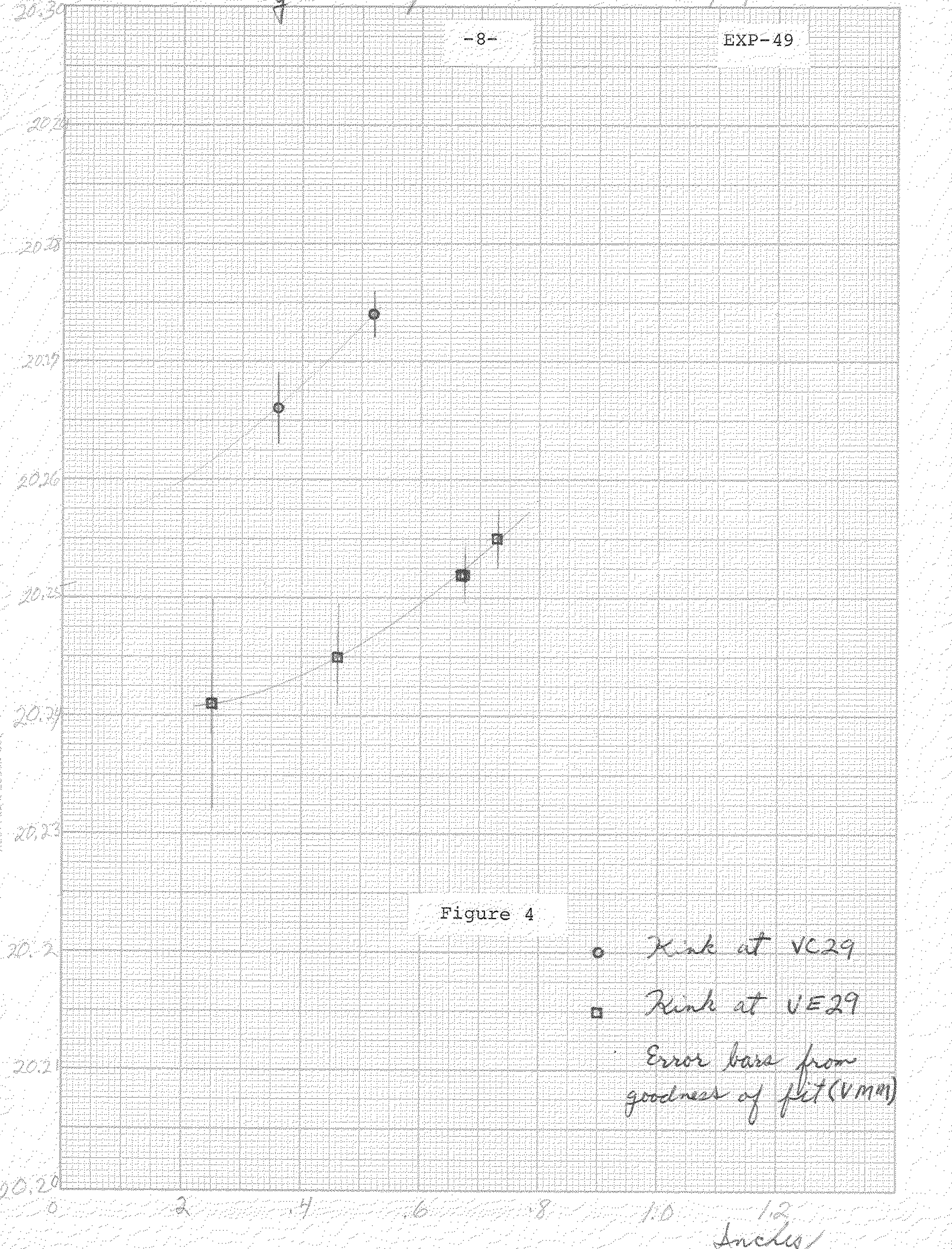

Figure 4